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Citation for published version:

Lee, J, Dima, M & Wright, M 2010, Exploration of direct bi-manual interaction in digitally mediated stop-motion animation. in *Proceedings of NordiCHI*. NordiCHI 2010 , pp. 635-638. <http://www.interaction-design.org/references/conferences/proceedings_of_the_sixth_nordic_conference_on_human-computer_interaction.html>

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Peer reviewed version

Published In:

Proceedings of NordiCHI

Publisher Rights Statement:

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Exploration of direct bi-manual interaction in digitally mediated stop-motion animation

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ABSTRACT

In this paper we present the development of a digital system prototype for character animation, with the primary focus on enabling direct bi-manual interaction through the employment of haptic sense and gestural control. The aim of the research is to explore the design of digital animation systems that build upon and augment the rich tacit knowledge embodied in the traditional creative practice of stop-motion animation. A team of highly skilled stop-motion animators participated in the design process of the prototype system evaluating and reflecting upon the key aspects of the design. We describe our design approach and the methodology employed in two design key studies framed around the concepts of direct tactile manipulation and two-handed interaction. We identify the components that enabled immediacy and enhanced engagement with the new system. The outcomes of the studies illustrate the system's potential for enabling immersive physical interaction in a digital animation setting.

Author Keywords

Animation, tacit knowledge, haptic I/O, embodied interaction

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation] User Interfaces – Input devices and strategies, Interaction styles, Haptic I/O, User-centred design

INTRODUCTION

Practitioners trained to work with digital media have access to a wide range of digital software which ease the production process, yet, little change has been made regarding the physical ways to interact with the digital workspace [5],[6]. Although in the research domain there is growing interest in exploring physical interfaces as a means

of interaction, in the mass-market the Window/Icon/Menu/Pointer (WIMP) and keyboard have been, in most cases, the predominant interfaces through which digital software are accessed. Arguably, those interfaces fail to communicate the richness and complexity of human gesture [12] and consequently, embodied skills cannot be accommodated properly in a digital setting. Hence, the tacit skills of traditionally trained practitioners cannot be utilized efficiently in digital workspaces.

We illustrate this issue in the dichotomy between traditional physical Stop-motion and digital Computer Graphics aided animation and further explore it as a case-study. Our design-led research explores the application of intuitive interfaces and creative mapping for transferring the rich tacit skills of traditional Stop-motion practice in a digital setting.



Figure 1. A stop-motion animator adjusting the head of a chrysalis character

Stop-motion is one of the earliest animation techniques. A physical object, usually an articulated character, is moved through different postures and photographed in each one of them. The photographs are then combined and played back in a fast sequence thus creating the illusion of movement. Today the process is being enhanced with digital cameras and digital recording software for the arrangement and playback of a sequence. The technique can be used, amongst others, for rigid or deformable objects such as clay. Animators who work with stop-motion develop a particular set of skills which unfold around unencumbered two-handed tactile interaction with the physical models (Figure 1).

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NordiCHI 2010, October 16–20, 2010, Reykjavik, Iceland.
Copyright 2010 ACM ISBN: 978-1-60558-934-3...\$5.00.

We focus on exploring the development of a hybrid system that connects the physical and digital animation practice, drawing on the concept of direct bi-manual¹ interaction which prevails in the traditional practice. In the following paragraphs we will describe the methodology that was used to develop our prototype. We will further present the results of the key-studies and the overall outcomes of the user tests, identifying significant points that need to be taken into account in future designs of such applications.

RELATED WORK

We have decided to employ physical interfaces as research has showed that, by being more apt to human motor-sensory and kinesthetic abilities, they create an enriched interaction space [5], [9], [12]. In their initial discussions with stop-motion animators, as described in the methodology section, they identified the lack of touch in a digital environment and the immense complexity of commercial animation packages to be salient drawbacks for working in a digital space. Following this comment, we employed, from the wide range of physical interfaces, haptic technology for the dominant hand gestures due to its ability to operate in 3-D space and simulate the sense of touch.

Haptic technology

Haptic devices allow the user to feel the surface of the virtual models by exertion of forces and vibrations to the user via motors. In addition, they are dynamically reconfigurable since parameters like the weight of an object, the stiffness of its surface and the material it is made of can be easily adjusted. A number of research projects make use of haptic devices to edit geometric paths of pre-animated virtual characters and adapt their motion in real time [1], [3]. These projects have explored the application of haptic technology in a limited area of digital animation. However, they have not considered the deeper implications of designing haptically-augmented systems which build upon the skills embedded in traditional stop-motion.

Tangible Interfaces

In order to investigate bimanual action, we followed Guiard's kinematic chain dictum of asymmetric division of labour in skilled bimanual action [4], and assigned tangible interfaces to the non-dominant hand which were used to perform secondary actions. Research projects which have explored the use of tangible interfaces for animation have, in contrast to our set-up, mainly employed them as the *central* gestural input to control locomotion of digital characters. Oore et al [9] presented a physical interface for low-level control of a digital character where the input device consisted of two motion trackers embedded in two bamboo rods. Tangible Handimation employed three Wii Remotes to control parts of a character. The goal of the project was to *'explore more expressive interaction, with*

the hopes of making use of tacit knowledge animators have that do not easily map to current computer interfaces' [11]. Monkey 2 [7] was a tangible input device comprised of individual pieces that could be combined to form a skeleton. The product, which is now discontinued, was used to perform instrumented puppetry.

METHODOLOGY

Throughout the whole process, we have collaborated with a team of three stop-motion animators. Two were final year animation students at Edinburgh College of Art, and the third was working as stop-motion technician at the same College. All three were specialized in modeling and animating physical objects and characters, both human and non-human. Through a collaborative process, we followed an analysis-composition-synthesis design model.

Analysis – Composition – synthesis model

We observed the animators during studio practice over a period of time and conducted a series of in-situ discussions in order to gain in-depth knowledge and analyse the bi-manual tactile interaction between the animator and the animated character. The outcomes of this contextual investigation were combined to construct a series of design key studies. These studies aimed to explore user's perception of the new, digital workspace by framing direct bi-manual interaction as the central element under investigation. All initial investigations and evaluation sessions were recorded in video to capture bodily motions and gestures as they unfolded in time.

Constructing design key studies

Two main key-studies were defined based on two important physical elements of stop-motion: The direct tactile manipulation of a puppet and the bi-manual interaction. For every study a system prototype was built, where functionality was restricted to the main element under investigation. Each study included a series of design iterations aimed at refining the initial prototype by developing the software and adjusting the hardware. The reason behind restricting the functionality of the system prototypes to each particular element under investigation was that we sought to focus on in-depth evaluation of each element separately. In the end, all elements were combined to a final prototype and further tests were carried out.

Evaluation

Intensive 'hands-on' experimentation facilitated our understanding of the requirements of a group of people with a certain expertise which is primarily exercised than verbalised or even sketched down on paper. Moreover, our system employs physical interfaces which need to be used and 'felt' before the exact design of their use is determined. By involving our end-users in an iterative and interactive 'hands-on' experience, we create an open-ended evaluation space apt to revealing unexpected, emergent aspects of their practice and challenges for our design. Video recordings provided insightful complimentary clues.

¹ Using or requiring the use of both the dominant and non-dominant hand

CONDUCTING THE KEY-STUDIES

The workspace (Figure 2) was a 2^{1/2}D space on the computer screen with no other graphical user interface apart from a text area that displayed the performed actions and kept track of the Key-frames² timeline. Keyboard buttons were used for the basic animation actions such as Set/Advance/Retrace a Key frame and Stop/Playback animated movie sequence. A 3-D sphere represented the haptic device in the digital space and followed its movement. The virtual scene included a customizable 3-D background and a set of virtual characters modeled as rigid bodies. A Skeleton, a hierarchical chain of bones and joints, was attached to each body and was given dynamic properties through a kinematics algorithm. There are two main kinematic algorithms, Forward (FK) and Inverse Kinematics (IK). In FK, if a bone is moved or rotated, the bones that follow it in the chain move accordingly. In IK, motion of an end bone determines the motion of the chain (i.e. if fingers are moved then motion of all joints up to the shoulder is computed *automatically*). We have initially chosen to work with FK since the animators highlighted the necessity of having total control over the character's motion. For the same reason, we did not implement interpolation³ or other form of algorithmically-driven automated motion computation between posed frames. In order to keep the virtual space simple, no physics were implemented.



Figure 2. The 3-D virtual space. The white sphere is the visual representation of the haptic device

For each of the key-studies described below, the animators were asked to create an animation of one or more of the virtual characters based on a storyline of their choice.

²A Key Frame is a rendering of a specific position of the animated entities captured at an instance of time.

³Algorithmic computation of possible postures in the frames between the Key-frames so that there is smooth transition of motion between Key-frames

Design I – Haptic sense

We employed two haptic interfaces: the Sensable's Omni™, a stylus-type, six-degrees-of-freedom (DoF) haptic device and the 3-DoF Novint Falcon device which could not provide rotation (Figure 3).



Figure 3. The setup with Novint Falcon and the Wii Remote (left) and the Sensable Omni™ (right)

Both devices were used to map the primary gestures of the dominant hand in a mimetic way as the central control input. However, due to each device's specifications, different configurations were tested for each device. For the Omni™ we exploited the three rotational degrees and we created a mapping in which the animator rotates the joints of the skeleton in order to move the bones. For the, limited to translation only, Falcon, and because we worked with FK, translation of the bone was designed to produce rotation on the corresponding joint (Figure 4). The animators were asked to use each device in turn.

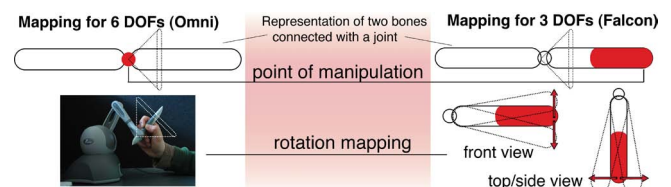


Figure 4. Mappings for bone control for each haptic device

The animators were impressed by the sense of touch and confirmed that it enhanced the interaction with the characters in the digital setting. The first problem we encountered was that the 3-D work space of the haptic device was not directly perceivable. The animators would often move the camera to get closer to the character instead of moving the visual representation of the device. To assist perception of the 3-D space, we discussed the necessity of visual cues which indicate when a character or parts of it are selected.

The 6 DoFs Omni™ stylus device was overall preferred due to the extended freedom of action it provided. The device was also regarded delicate and precise enough to perform subtle actions that deform the character, e.g for facial animation. However, the action of selecting and moving a bone, as performed with the Falcon device, instead of rotating the joints felt to them '*closer to stop-motion*'. This was an interesting realization for further development. Although FK is used in digital 3-D animation to provide

user controlled motion and our original thoughts were that it would act in the same way for stop-motion, we realized that the way stop-motion animators work is 'translated' as a combination of FK and IK. The tactile feedback augmented their engagement with the system but the fact that they could not seamlessly manipulate the different parts of the character subsided the immersiveness of the interaction.

Design II – Bimanual interaction

The interface of the non-dominant hand was used to control several cameras. Six cameras in total were placed in the virtual scene. Five were positioned in each direction, one was placed at the top and one was placed in front of the character and acted as its eyes. This last camera was designed into the system after observing during studio work that the animators often used 'first-person' viewpoint for creating parts of the animation. Each camera would become the main viewpoint by pressing a keyboard button.

Moving the camera was originally assigned to the 3-D Connexion's Space Navigator, a 3-D mouse with 6 DoFs offering control of zooming, panning, spinning, tilting and rolling. From the first evaluation sessions, it derived that the 3-D mouse did not prove to be an adequate controller for navigating in the digital space. It was regarded as a rather static device, an extended joystick. Its functionality did not support smooth navigation, limiting seamless direct engagement with the system. Further discussions regarding freedom of motion in two handed practice led to the decision of testing another gestural interface.

For this purpose we selected the Wii Remote and conducted further tests with different configurations to discover the setup that corresponded to the preferred camera movement. The Wii Remote provided more freedom of motion and more direct response to the animators' gestures. Its motion also eased the design of a seventh camera with the functionality of orbiting around the character for quickly changing the angle of view.

When we combined both interfaces, we observed that by assigning to the Wii Remote the task of translating/rotating/orbiting the camera and using the haptic interface on the dominant hand, we create an asymmetric way of working with the hands, encountered in many two-handed practices including stop-motion.

DISCUSSION

The kinematics issue showed that the design space is formed around the mapping of user's gestures to character motion. The fact that the animators were interacting with the system through a device led us to observe the difference between using a tool as opposed to directly interacting with the hands. We recognised here the possible test of other interfaces as input devices such as data gloves augmented with vibro-tactile feedback via sensor motors. However, in

order to achieve unencumbered embodied interaction with the character in the 3-D virtual space, it is important to identify first the limitations and abilities of the selected physical interface and then to carefully instrument how it will act as a mediator of the users' gesture.

The need for visual cues was a sign of the close and complimentary connection between visual and haptic perception. It is essential that future designs take into account and exploit the power of visual feedback combined with well-designed mappings to ensure continuity of artistic experience in the new setting. The above outcomes apply to how successfully the action of animating becomes embodied in the final hybrid system.

As a final remark, our method of iterative system prototyping, restricted to one study element each time and the hands-on sessions proved to be ideal for eliciting the local tacit knowledge and informing the design in a rigorous manner. Interdisciplinary collaboration with a group of creative practitioners provided a fascinating ground for engaging in HCI design by creative practice.

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